

REPORT OF EXPERT WITNESS

BOARHEAD FARM AGREEMENT GROUP V. ADVANCED ENVIRONMENTAL TECHNOLOGY CORPORATION, ET AL.

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1. SUMMARY OF BASIS OF OPINION

The following opinions are based upon my professional experience, described in detail in section 5, in the fields of chemistry, process development, hazardous waste production, waste management, and hazardous waste site investigation and remediation. In addition, documents referenced in section 3 were used in developing these opinions.

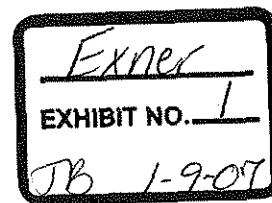
2. STATEMENT AND BASIS OF OPINIONS

I have reviewed the cited documents describing manufacturing processes and chemicals used by the companies described below. I have used the information and my experience to identify the types of wastes that were generated by the companies' manufacturing processes and to estimate the approximate composition of the waste streams.

Chemical wastes generally arise during the following operations:

- Chemical reaction
- Hydrolysis or neutralization of the reaction mixture
- Product purification by crystallization, decolorization, clarification, precipitation, distillation, or extraction
- Separation of solids by filtration
- Separation of liquids by phase separation, distillation, or steam stripping
- Drying, blending, and formulating
- Spills, leaks, and equipment cleaning

The companies processing steel and those manufacturing metal parts and printed circuit boards used specific processes that generated wastes from acid pickling and plating. These operations also generated rinsate wastes, spills, spent reagent baths, and sludges. Lubrication of metals and degreasing also formed residual oil and grease wastes and chemical wastes containing solvents such as trichloroethylene (TCE) consistent with the specific process.



I used available information to define the processes used during the 1970's, the types of wastes that were produced from these processes, and the manner in which the wastes were collected to form an opinion about the wastes that each company generated and disposed of off-site.

CHEMICAL PROCESSING

Diaz and Ashland manufactured selected chemicals in batch mode according to market demand. Such operation generates chemically contaminated waste streams from the following activities:

1. Chemical processing. During chemical reactions, the desired product is formed concurrently with by-products. Consequently, purification/separation steps are necessary. Separation of the product from reagents and by-products by a variety of purification steps leaves behind liquid and solid chemical process wastes. Such wastes may include crystallization mother liquors, process water washes, extraction solvents, spent catalysts, spent adsorbent and drying agents, product purification filter cakes, distillation residues, distillation overheads, scrubber solutions, and vacuum system condensates.
2. General equipment operation. Chemical wastes from this category include improper phase separations, unwanted emulsions, cleaning of equipment, cleanup of spills, spills to land from leakage of pipes, pumps, and valves, laboratory wastes, disposal of old equipment and insulation, and housekeeping wastes.

Each chemical process generates a variable quantity of chemical waste per pound of product depending on the efficiency of the chemical reaction and the attention of operators. Chemical process wastes are affected by the selectivity of the chemical reaction, choice of reagents, difficulty of purification and separation, recycle and re-use of reagents and solvents, water re-use or pre-treatment, and equipment configuration.

DIAZ CHEMICAL CORPORATION

During the period of 1975 through 1977, Diaz Chemical Corporation manufactured custom chemicals. The primary product, 4-chloro-3,5-dinitrobenzotrifluoride (CDNBF), was manufactured in 2,000-gal reactors by the successive nitration of 4-chlorobenzotrifluoride (CBF). The nitration was carried out in two stages [Chiras deposition]. In the first step, CBF was converted to 4-chloronitrobenzotrifluoride (CNBF). In the second step, an excess of nitric acid, sulfur trioxide, and sulfuric acid converted the mono-nitrated material to CDNBF. The excess acid layer was separated and used to nitrate a new batch of CBF. After this recycled acid stream formed the mono-nitrated intermediate, the acid stream was separated from the organic layer. This organic layer was then treated with a new batch of fresh acid solution. The CDNBF was washed with water and low concentration alkali solution [Chiras]. A patent of the period describes this process [Schneider, L., Graham, D.E., US Patent 4,096, 195, June 20, 1978].

Each batch of CDNBF produced about 1,000 gal of spent acid waste consisting of about 83 % sulfuric acid, about 3 % nitric acid, 10-12 % of water, and about 2 -4 % organic material [BSAI 029271, BSAI 029272]. The organic impurities in the acid waste were likely CNBF, sulfonated

CNBF, chlorobenzoic acid, chloro-nitrobenzoic acid, and CDNBF [BSAI 029140]. Organic impurities likely varied depending on batch operating conditions such as reaction time, care in carrying out phase separations, and temperature. The teachings of the patent produce a calculated, spent acid waste stream of about 82 % sulfuric acid, 3 % of nitric acid, 12 % of water, and 3 % of waste organic. These wastes were disposed of off-site [Landmesser deposition V 2].

Wash waters for each batch were about 360 gal [BSAI 029279] containing low concentrations of sodium sulfate, nitrate, and probably less than about 0.3 % of the waste organic constituents.

During the period of 1975-1977, Diaz produced spent acid waste consisting of about 83 % of sulfuric acid, 3 % nitric acid, 10-12 % water, and 2-4 % of organic material. This waste was disposed of off-site. In addition, Diaz produced wash waters containing salts and low concentrations of organic compounds.

ASHLAND CHEMICAL COMPANY

During the period of 1975-77, Ashland Chemical Company's Great Meadows plant in New Jersey manufactured a wide variety of custom chemicals for outside clients. Yearly production of 25-30 products was carried out in 100-4,000-gal reactors in batch mode. Wastes formed during the production would have been defined by specific processing for each product and was representative of methods used in custom manufacturing during this time period. Primary sources of wastes requiring disposal would be expected to be solvents such as water, hydrocarbons, or alcohols that were used as reaction media or for purification of the products. These solvents would be expected to contain excess reagents, reaction by-products or other impurities. Recovery of solvents by distillation would yield distillation residues containing solvent, reaction products, and product. Products, solvents, reagents, and by-products from spills and from reactor and line cleanout would produce waste material for disposal. Occasional off-specification product would require disposal if the material was unsuitable for blending with fresh product.

4-chloro-3, 5-dinitrobenzotrifluoride (CDNBF)

The largest quantity of material produced during this time period was CDNBF, an intermediate for various herbicides. CDNBF was produced by nitration of chlorobenzotrifluoride in 4,000-gal reactors. An average of 1.5 batches per day were doable [Curley, 96, p. 138]. At the conclusion of the nitration reaction, spent acid, about 2,400 gal/batch [Curley 04] was separated from the product. This spent acid contained about 83 % sulfuric acid, 3.5 % nitric acid, 0.1 % hydrogen fluoride, about 10 % water, and about 3-4 % of organic compounds [ASHL00002-3, ASHL00004]. Organic compounds in the acid waste would be chloronitrobenzotrifluoride (CNBF), sulfonated CNBF, chlorobenzoic acid, chloronitrobenzoic acid, and CDNBF. The amount and composition of organic impurities would depend on batch operating conditions such as reaction time, care in carrying out phase separations, and temperature. The composition of the waste is consistent with the teachings of a patent of the time [Schneider]. Calculating the waste stream composition from the patent gives a spent acid waste stream of about 82 % sulfuric acid,

3 % of nitric acid, 12 % of water, and 3 % of waste organic compounds, very similar to the composition described above.

CDNBF product was subsequently washed to remove and neutralize residual acid. Wash waters for each batch were about 800 gal [BSAI 0033355, Curley 11] and would contain low concentrations of sodium sulfate, sodium nitrate, and less than about 0.3 % of the waste organic constituents.

During the period of 1976-1977, Ashland produced large quantities of spent acid waste consisting of about 83 % of sulfuric acid, 3 % nitric acid, 10 % water, and 3-4 % of organic material. This waste was disposed of off-site. In addition, Ashland produced large quantities of wash waters containing salts and low concentrations of organic compounds.

Dyes

During the period of 1976-1977, Ashland produced 8-15 hair dyes and intermediates for Clairol [Curley, 04, p.35]. Clairol hair dyes in 1970 included the following compounds [Ames, B.N., Kammen, H.O., Yamasaki, E., 1975, "Hair Dyes are Mutagenic: Identification of a Variety of Mutagenic Ingredients," Proc. Nat. Acad. Sci. USA, 72, 2423-2427; Corbett, J., "An Historical Review of the use of dye precursors in the formulation of commercial oxidation hair dyes," Dyes and Pigments, Vol. 41, 1999, p. 127-136]:

- ☐ 4-amino-2-nitrophenol,
- ☐ p-phenylenediamine,
- ☐ 2,5-diaminotoluene,
- ☐ N-phenyl-p-phenylenediamine,
- ☐ 2-aminophenol,
- ☐ 3-aminophenol,
- ☐ m-phenylenediamine,
- ☐ 2,4-diaminotoluene,
- ☐ 2,4-diaminoanisole,
- ☐ 2,4-diaminodiphenylamine,
- ☐ 2-nitro-p-phenylenediamine,
- ☐ 4-nitro-o-phenylenediamine.

Clairol hair products today contain many of these compounds including 2-nitro-phenylenediamine, nitroamines, nitrophenols, and blue, red, and orange colors derived from nitrophenylenediamine [National Institutes of Health, <http://householdproducts.nlm.nih.gov/cgi-bin/household>, 6/2006]. All of these compounds are derived from fundamental dye chemistry involving nitration of halogenated benzenes, subsequent reduction to anilines and phenylenediamines, and reaction of these chemical intermediates to form the final product [Ventakamaran, K., "The Chemistry of Synthetic Dyes," Vol. I, Academic Press, New York, 1952]. Ashland produced chlorodinitrobenzene [Olasin, p. 201]. It is likely that Ashland carried out nitration reactions in making Clairol products with attendant acidic dye wastewaters containing nitroanilines and nitrophenols.

Celleri describes one of the dyes as nitroaminophenol [Celleri, p.23], and Curley [1996, p.61] recalls that nitration was a process step in one of the hair dyes. Clairol used 4-amino-2-nitrophenol in their formulations in 1970 and 1984. It is likely that Ashland manufactured nitroaminophenol. Dye wastewater from such a process would contain high concentrations of nitric and sulfuric acid and about 10-20 % of organic reagents, products, and by-products.

In the period of 1964-1977, Clairol was very active in applying and modifying nitrophenylenediamines for hair formulations [Brunner, W.E. et al., 1966, US 3,274,249, "Derivatives of 1,4-Diamino-2-Nitrobenzenes"; Brody, F., Pohl, S., 1975, US 3,884,627, "Oxidative Hair Dye Compositions"; Bil, M.S. 1976, US 3,959,377, "Method for Preparing 2-Nitro-4-AminoN-Phenylaniline"; Halasz, A., Cohen, D., 1977, US 4,021,486, "Hydroxyalkyl-Aminonitrodiphenylamine Compounds Useful as Hair Dyes"; Steinland, R. et al., 1978, US 4,119,399, "Composition for Coloring Hair..."; Bil, M.S., 1981, US Re. 30,798 (3,632,582 / 1972), "Process for preparing Nitro-p-Phenylenediamines". A large number of chemicals related to nitrophenylenediamines was prepared and tested. The fundamental reactions included nitration of fluoroaniline to prepare fluoronitroaniline. This key intermediate was then converted to a variety of compounds by substitution of the fluoride group. These derivatives included reaction products with ethylene oxide to yield HC red # 3 and HC blue # 2.

Curley states that the following hair dyes were produced by Ashland:

NOPD (nitro-o-phenylenediamine), NPD (presumably nitrophenylenediamine), P-101, PU 020, P-025, P-116, P-150, P-153, P-154. Also, reference is made to waste components P-109 and P-154, presumably other hair dyes that were produced, in addition to DNTA, NDAPA, and 4-nitro mother liquor. Curley [1996, p. 175] and Celleri [p. 23] state that a common reagent for the hair dyes was nitrofluoroaniline. It is highly likely that many of the hair dyes were prepared according to the reactions of different amines and aminophenols with nitrofluoroaniline as described in the various patents. Upon filtration of the dyes, the dye mother liquors would contain small amounts of dye products and about 5-20 % of reaction by-products such as dimers and nitrophenols.

The chemistry in producing Clairol hair dyes and intermediates matches the capability of the Ashland plant. Product purification commonly involved filtration or centrifugation of solid products. The filtrate was dye mother liquor, which contained toxic components such as reaction by-products, undesirable product isomers, dissolved product, spent acids, and salts. These mother liquors were disposed of off-site. Subsequent washing of the filtered material produced further wash waters containing salts and reaction by-products. In May 1977, about 30,000 gal of dye wastewater was produced [Curley 9].

Phthalide

Ashland produced phthalide, a useful intermediate for pharmaceuticals and dyes. Curley recollected zinc oxide as a reaction product because it gave them troubles in waste treatment. Phthalide can be prepared from phthalimide by reaction with zinc, a small amount of copper, and sodium hydroxide [Organic Syntheses Coll. Vol. II, p. 526, 1943]. Upon final acidification, the

phthalide is filtered. The filtrate would contain acid, acid salt, and zinc and copper ions, in addition to about 30 % organic by-products. These are likely to be phthalic acid, phthalimide, phthalide, and hydroxymethyl benzoic acid. Such a process is consistent with the description of the phthalide waste stream as containing 1.5 % sulfuric acid and 32 % sodium sulfate during this period [ASHL00002-3]. It is likely that during the 1976-1977 timeframe, phthalide was used to prepare phenoxymethylbenzoic acid [Curley, 1996, p. 147].

Ashland generated an acidic waste stream from phthalide production containing about 1.5 % sulfuric acid, 32 % sodium sulfate, about 30 % organic by-products, and zinc and copper sulfate. Water washes and recrystallization water with correspondingly lower concentrations of chemicals also were generated.

Miscellaneous Products

Ashland produced other products including CMPA (cyclomethylpropylamine), DBHMDA (dibutylhexylamine), TPS in benzene solvent (triphenylsulfonium chloride according to Celleri), anti-oxidants, and physically treated (ground) phenolic resins. Wastes such as distillation residues and filtration liquids would likely have been produced.

Diphenylacetonitrile (Dipan). Ashland produced diphenylacetonitrile with an attendant wastewater and distillation residue. The wastewater contained 14 % aluminum chloride that was hydrolyzed, 1 % hydrogen chloride, 3 % aluminum salts, and about 10 % organic material such as reaction by-products and benzene [ASHL00002-3]. Such a waste stream is reasonably consistent with an accepted synthetic method for this product [Harrison, I.T., Harrison, S., "Compendium of Organic Synthetic Methods," Wiley Interscience, NY, NY, 1971, p. 474]. Purification of this material by distillation would have led to tar residues [Curley, 1996, p.150].

Ashland generated a variety of organic solvent wastes from solvent use as reagent, solvent, or purification medium during production of various chemicals.

STEEL PROCESSING

Processing of steel involves a number of metal treatment processes depending on the type of material that is being produced [USEPA, "Profile of the Iron and Steel Industry, EPA/310-R-95-005, September 1995]. Hot and cold forming of the metal improves mechanical properties, machinability, size accuracy, or thinner gages. Metals are commonly treated to remove mill scale, rust, oil, and other foreign substances. This process may involve solvents, air, abrasion, or alkali and acid pickling. During cold forming of wires, tubes, sheets, and strips, lubricants are used. These lubricants generally are fatty acids such as ricinoleic acid or derivatives, mineral oils, or emulsions of the two types of lubricants [Meisters, I.D., "Water Soluble Lubricants," US 3,720,695, 1972; Loftus, T.J., "Reconditioning Oil used in Cold Working metal," US 3,793,184, 11974]. Because steel can become brittle during these actions, it is generally annealed subsequently. Before annealing, the surface is generally cleaned with alkali-water rinses.

Acid steel pickling for surface cleaning generally involves hydrochloric or sulfuric acid. Some stainless steel or steel alloys are pickled with nitric and hydrofluoric acids because hydrogen chloride can have a negative effect on the metal properties. Pickling is accomplished by dipping metal parts or wire into acid baths in batch mode or by moving the metal through a pickling bath or spray. Metal parts are removed from baths and rinsed with large quantities of water and alkali.

Steel is protected further by coating it commensurate with its final use. Coating may consist of chemical plating, electrolytic plating, painting, and polishing.

Each of these steps uses chemicals that eventually yield wastes. During cold rolling, water-soluble oils are used as coolants and removed with basic water solutions. During temper rolling, mineral oils decrease friction. Metal cleaning can yield solvent wastes and sludges. Pickling yields acid and alkali wastes containing used chemical reagents and an accumulation of surface materials from the steel. Salts and oils accumulate in the rinses. Plating chemicals may contain metal ions such as zinc, tin, lead, copper, nickel, or chromium, and complexing agents such as cyanide ions.

NRM INVESTMENT COMPANY (NRM)

NRM's Malvern, PA, plant processed hot rolled steel throughout the period of 1974-1979. Other owners operated the mill before and after NRM in the same general manner from 1962 to 1989 [Wilmer, J. W. Jr., Letter to USEPA, July 14, 1993; Winters deposition]. The following operations occurred [Wilmer; Fackenthal, E. Response to Interrogatories, July 24, 2004] :

1. Pickling. Hydrochloric acid was used to remove scale and oxidation products from the steel. The treated metal was rinsed successively with aqueous sodium hydroxide and water. This process produced two waste streams, spent pickling liquor and pickling rinsate.
2. Cold rolling in Sendzimir mills (Z mills). This process used a water-soluble oil as coolant. The oil became part of a waste stream after the following cleaning process.
3. Cleaning after Z milling removed the oil with aqueous sodium hydroxide washes.
4. Annealing at about 1,200 ° F in a reducing atmosphere.
5. Temper rolling during which a light mineral oil reduced friction. A light oil rust preventative was applied. The oil became part of the following cleaning waste stream.
6. Plating. The metal was cleaned again with hot aqueous sodium hydroxide and rinsed with water. A zinc coating (galvanizing) was applied electrolytically in the presence of sodium hydroxide and sodium cyanide. Nickel plating also was carried out.
7. Painting.
8. Slitting and trimming.

The largest waste streams from these operations were pickling liquors and pickling liquor rinsates. About 10-15 % w/w of hydrochloric acid was used for pickling depending on the type of steel [Freda]. The plant also pickled steel from other steel producers. Purchased hydrochloric acid was generally diluted with two volumes of water per one of hydrochloric acid [Piotti]. This dilution results in a 14 % solution of hydrochloric acid, in agreement with Freda's recollection.

The pickling capability of this acid became unacceptable at 4- 6 % hydrochloric acid and a resulting ferrous chloride concentration of about 20-30 %. In the 1970's, pickle acid reclamation of hydrochloric acid was carried out at about 3,000 gal/day when the reclamation was operating well [Piotti]. This reclamation produced pickle liquor for disposal of about 3-4 % hydrochloric acid and about 30 % ferrous chloride [Freda]. In 1987, when waste reduction had undoubtedly reduced wastes considerably relative to the early 1970's, the pickle liquor rinsate also contained trace amounts of chromium, zinc, nickel, copper, and cyanide [Wilmer]. In the period of 1970-1977, the plant required about one load (3,800 gal) of fresh hydrochloric acid for meeting production of the pickling line [Piotti, p. 75]. Such a usage level would translate to about 11,000 gal/day of spent pickle liquor, reasonably consistent with Piotti's recollection of five 5,000-gal tank trucks of waste being moved out on busy days. Spent pickle liquor was stored in two 10,000-gal holding tanks.

The acidic pickle liquor adhering to the pickled steel was subsequently washed with sodium hydroxide solution and rinsed further with water. Before the late 1970's when a filtration system was put in place, this rinsate was collected in a concrete holding pit of approximately 15,000-gal capacity. Other rinsates from cold rolling and from the plating baths were also collected in this pit [Winters dep., Piotti dep.]. These rinsates contained neutralization salts and traces of heavy metals and cyanides. In the mid-1970's, this rinsate waste was disposed of off-site at a daily rate of at least 18,000-30,000 gal.

Concentrated wastes from the ten plating baths contained cyanide, base, and high concentrations of zinc. These liquids were disposed of separately from the pickling wastes.

Lubricants and cleaners from rolling were collected in an oil-water pit. Oil was separated, re-used or disposed of, liquids were re-used or disposed of, and sludges were disposed of.

In the early to mid 1970's, NRM produced large quantities of spent pickle liquor containing about 4 % hydrochloric acid and about 30 % ferrous chloride. NRM also produced large quantities of rinsates from pickling, cleaning, and plating which contained oil and grease, cyanides, and heavy metals such as zinc, chromium, copper, and nickel. These streams were disposed of off-site.

CARPENTER TECHNOLOGY CORPORATION

Carpenter's Reading, PA, plant produced stainless steel and high-temperature steel alloy wire, strip, and bars during the period of 1970-1980. In 1969, Carpenter produced about 50 % stainless steel that was pickled with a variety of acids. About 20 % of its production, electronic, magnetic, and electrical alloys, was pickled with sulfuric and hydrochloric acids, about 15 % of production, tool and alloy steels, was pickled with sulfuric or nitric acids, and about 15 % of its production, high-temperature alloys, was pickled with nitric and hydrofluoric acids [Mann exhibit 10]. Steel was dipped into acid baths from overhead suspensions and rinsed after pickling with water in separate baths [Adams dep]. These acid streams were sent from the pickling baths to three different acid storage tanks via dedicated piping [Elbert dep]. Tanker

trucks removed the acid wastes for off-site disposal. In 1969, about 38,000 gal/month of sulfuric acid, 108,000 gal/month of nitric acid/hydrofluoric acid, and about 135,000 gal/month of hydrochloric acid were produced [Mann 10]. Rinse waters were treated in the on-site wastewater treatment plant. Residue from this treatment resulted in on-site storage of metal sludge in lagoons at the rate of about 5,000 tons/year [Mann 10].

In 1973, about 460,000 gal/month of acid were disposed of off-site, and in 1974, about 360,000 gal/month of acid were disposed of off-site. The composition of these acids was analyzed from September, 1972 to July, 1974 [Mann 3]. Table 1 summarizes the average composition (14 samples) of three different acid waste streams. Special waste analyses are an average of 10 samples. Weight percentages for the acids were calculated based on initial acid concentrations of 37 % for hydrochloric acid, 94 % for sulfuric acid, 68 % for nitric acid, and 70 % for hydrofluoric acid [C018468]. In early 1971, purchased concentrations of 32 % hydrochloric acid, 93 % sulfuric acid, 65 % for nitric acid, and 70 % for hydrofluoric acid are described [Mann 15].

Table 1. Average Weight Percent Composition of Carpenter Waste Pickling Acids between 1973-July 1974

Compound	Hydrochloric Acid	Nitric Acid	Sulfuric Acid	Special Acid
Hydrochloric	17	0.2	0.5	9.6
Hydrofluoric	0.2	2	0	0.1
Nitric Acid	0.8	8	1	2.3
Sulfuric Acid	0.9	0.1	15	<0.1
Iron	3.4	1.5	1.1	1.4
Nickel	1.1	0.3	0.1	1.1
Chromium	0.5	0.2	0.2	0.2

These compositions of acid waste streams for 1973-74 are in general agreement with those described by Mann in February, 1971 [Mann 15]. In 1971, the acid waste streams also contained other metals in accordance with the composition of the steel that was cleaned. The hydrochloric acid stream, for example, contained about 0.05 % cobalt, 0.02 % copper, 0.03 % manganese, about 0.01 % of magnesium, < 0.01 % phosphorous, 0.003 % of titanium, and 0.02 % of vanadium in addition to iron, nickel, and chromium concentrations similar to those of Table 1. The compositions are also consistent with the description of the Carpenter waste hydrochloric acid stream in 1974 as being 14-20 % of hydrochloric acid and 7 % ferrous chloride [Adams 3].

From 1972 to 1973, Carpenter disposed of off-site large quantities of corrosive hydrochloric, sulfuric, hydrofluoric, and nitric acids containing, on average, up to 34,000 ppm of iron, 11,000 ppm of nickel, 5,000 ppm of chromium, and several other heavy metals.

TECHALLOY COMPANY, INC.

The Rahns, PA plant produced specialty steel wire and strip products in the period of 1967-1979. The manufacture of stainless steel, Inconel, Monel, and Nickel parts included the following operations:

- Cold rolling with Z mills, annealing, cleaning, and slitting
- Wire drawing, pickling, and annealing.

The pickling process used 20 % hydrochloric acid, 20 % sulfuric acid, 2 % hydrofluoric acid, and 5 or 10 % nitric acid [Energy Impact Associates, 1980, "Evaluation of TCE Contamination at Rahns, Pennsylvania,"]. Spent liquors were siphoned from the pickling tanks into a trench below the tanks [Hahn deposition]. This trench connected via a pipe to an underground pit. Material was pumped from this pit to an overhead storage tank from which it was transferred to tanker trucks for off-site disposal. At another plant processing stainless steel and alloys containing nickel and chromium [Carpenter], spent acids contained 4-6 % acids, 15-20 % ferrous chloride, and percentage amounts of nickel and chromium.

Rinsates of the pickled steel with sodium hydroxide and water were also placed into the trench. These solutions contained sodium salts of the pickling acids, iron, and small amounts of nickel and chromium.

Trichloroethylene (TCE) was used a degreaser at an average of about 1,200 gal/year between 1976 and May, 1979 [Interrogatory, 02/85] and from 1969 to 1977 [Roeder, W.V., letter to US EPA, December 18, 1992]. TCE was filtered and re-used as much as possible. TCE sludges were placed into drums and disposed of off-site. Alternatively, TCE was placed into barrels for evaporation and sludge was placed into the acid holding pit [Czerpak]. DiDomenico, who was in charge of the pickling house, stated in a 1979 interview that spent TCE was placed into the underground acid pit [Energy Impact Associates].

Laboratory wastes were placed into the trench [Stufflet dep]. All types of wastes were placed into the trench according to Czerpak [deposition, p. 31].

In 1979, groundwater contamination by TCE near the Rahns plant was traced to the leaking trench and pipe in the pickling house. The groundwater contamination had a pattern similar to contamination by acids, chloride ions, sulfate ions, nitrate ions, and fluoride ions. These data are consistent with the conclusion that TCE and acidic pickle liquors and rinsates were mixed in the trench and underground pit and leaked into the subsurface over a period of time.

Techalloy disposed of large quantities of pickle liquors containing percentage amounts of hydrochloric, sulfuric, nitric, and hydrofluoric acids. These pickle liquors contained about 20 % ferrous chloride and percentage amounts of nickel and chromium. Combined with these liquids was TCE from degreasing operations. Rinsates from pickling were also stored in the same pits and disposed of off-site.

HANDY & HARMAN TUBE COMPANY

In the 1970's, Handy & Harman Tube Company (Handy) manufactured small diameter, precision tubes at Norristown, PA. Materials were primarily SS 300, containing about 8-12 % nickel and 18-20 % chromium, and nickel-based alloys containing up to 70 % nickel [Curran deposition]. The process included the following steps:

1. Acid cleaning (pickling) in nitric acid, about 20 %, in nitric acid/hydrofluoric acid mixtures (10 % nitric acid/3-4 % hydrofluoric acid), sulfuric acid, and hydrochloric acid. Pickling occurred in four cleaning baths of about 40 ft x 3 ft x 3 ft and included rinsing of the materials. Rinsates and spent acids were pumped to two storage tanks in the basement. This procedure is typical of acid cleaning operations in the steel processing industry and is expected to generate wastes containing acids at percentage concentrations and nickel and chromium heavy metals in the thousands of ppm concentration. Rinsates contain the same constituents at lower concentrations. These wastes were disposed of off-site [Curran, Kollmar depositions].
2. Cold drawing the lubricated tubes through dies to reduce the diameter of the tube. Lubricants were hydrocarbon-based oils [Curran].
3. Degreasing with trichloroethylene (TCE) to remove lubricants in a degreasing bath of approximately 10 ft x 15 ft x 3 ft. This procedure generated two types of wastes for off-site disposal in drums. When the TCE became saturated with lubricant, it was distilled. Distillation residue consisted of about 50 % TCE, 50 % lubricant, and metal particles and other solids [Flax, M.E., September 16, 2004, Response to Interrogatories]. Second, over time, solid particles, dirt, TCE, and lubricant accumulated in the bottom of the degreasing bath. These sludges were cleaned out periodically. These TCE-containing wastes were disposed of as industrial waste in drums. In the 1970's, TCE was replenished at 2,000 lbs per approximate 6-8 week period [Kollmar].
4. Annealing to soften the metal for further size reduction.

The above processes were repeated depending on the customers' specifications.

Small amounts of waste were generated from methyl ethyl ketone or acetone that were used for tool cleaning. These occasionally entered the general plant streams but were generally disposed in 30-gal drums. TCE was also disposed of in a cistern, and lubricating and waste oils were used for dust control on a former parking lot [RMC Environmental Services, Inc., September 1992, Site Investigation, Handy & Harman Tube Co., Norristown, PA]. These types of disposal practices were common in the 1970's. The basement in which the acid storage tank was located also housed the maintenance and plumbing departments. It is likely that degreasing solvents, including TCE, were placed into the waste tank occasionally.

During the 1970's, Handy & Harmon generated acid wastes containing hydrochloric, sulfuric, nitric, and hydrofluoric acids from their pickling operations and subsequent rinsates. The aqueous wastes contained nickel and chromium heavy metals and were disposed of off-site. Handy also generated TCE-containing wastes from distillation residue and from cleanout of sludge residues in the degreasing bath. These wastes were disposed of off-site in drums. It is

likely that the spent acids also contained TCE from disposal of TCE wastes in the spent acid storage tanks.

PRINTED CIRCUIT BOARD MANUFACTURE

The manufacture of physical structures such as printed circuit boards on which electronic components can be mounted includes a number of general operations [USEPA, 1995, "Profile of the Electronics Industry," USEPA/310-R-95-002]:

1. **Board Preparation.** Generally, photographic methods transfer the circuit pattern to copper boards mounted on epoxy resin or fiberglass. Holes are drilled to provide electrical paths between the layers and to mount components. The boards are then cleaned to remove particles from these operations.
2. **Electroless Plating.** First, holes are prepared to remove smeared resin. Electroless plating then coats a uniform layer of copper on the holes and the surface of the board to allow further electrolytic deposition. The boards are dried.
3. **Imaging.** Photoresists are applied to the board in areas in which the circuit pattern will not be set. The board is exposed to a radiation source and developed to remove unwanted areas of the resist. Light etching, usually with ammoniacal etchants, removes rust inhibitors and other metals. If stenciling is used, the protective layer is dried and exposed copper is etched away. Photoresist is removed with a stripper.
4. **Electroplating.** Copper is deposited electrolytically to build up the thickness to provide reliable conductivity between layers. This involves immersing the article into a bath containing various chemicals. A plating resist is applied. Generally, tin/lead solder is plated on the board to protect the circuit pattern. Ammoniacal and cupric chloride are primary etchants used to remove exposed copper foil. The board is rinsed and dried. The tin/lead layer is removed and the board is tested electrically.
5. **Soldering Coating.** Solder coating by immersion of the panel adds solder to copper components. The alloy, 60 % tin and 40 % lead, coats the pads and holes not covered by the solder mask. Excess solder is removed.
6. **Electrical and Mechanical Testing.**
7. **Assembly and Soldering.** Electrical components are attached to the board by soldering. The board is cleaned and dried.

All these processes generate waste streams from spent solutions, rinses and drag out, spills, and cleanup of machines and bath residues. A variety of chemicals are used depending on specific company and client.

FLEXIBLE CIRCUITS, INC. (FCI)

FCI manufactured printed circuit boards consisting of flexible circuitry and power busbars at the Valley plant beginning in 1968. In the 1970's, it carried out copper, nickel, and gold plating, etching, wave soldering, and the accompanying rinses. In the early 1970's, as much waste as possible, mostly rinsates, went to the sewer. Concentrated plating and etching solutions were

stored in underground tanks and disposed of off-site. In 1983, the process was described as follows [BSAI082785-BSAI082800]:

1. The raw material was purchased as a rolled copper, Kapton, and acrylic adhesive laminate.
2. The laminate was drilled.
3. The laminate was plated :
 - a. Degrease, rinse, and condition
 - b. Rinse twice
 - c. Micro etch with sulfuric acid/hydrogen peroxide (copper sulfate) and rinse
 - d. Catalyze with a tin and palladium colloid solution, rinse twice
 - e. Accelerate by removing tin
 - f. Electroless copper plating using formaldehyde, sodium hydroxide, and copper sulfate; rinse
 - g. 2 % sulfuric acid dip to remove oxides
 - h. Electrolytic copper plate
 1. Plate with copper sulfate to build up copper thickness, rinse
 2. Coat with light sensitive material, Riston
 3. Expose to white light to print image onto laminate
 4. Develop image in bio-degradable solution, rinse
 5. All copper exposed on the laminate is etched with cupric chloride (hydrochloric acid, hydrogen peroxide, water, copper); rinse
 6. Strip off Riston with an alkaline solution of butyl cellusolve; rinse
 7. Scrub laminate.
 8. All copper surfaces except interconnects are protected with a cover layer of Kapton and adhesive
 9. Interconnects are soldered by fluxing the laminate with rosin, dipping in a pot of molten solder, and removing excess solder with Freon

In 1968, effluent containing 40 ppm of copper was discharged to the local sewage treatment plant [BSAI082380]. In 1970, discharge water to ground contained 325 mg/l of copper [BSAI082558]. In response, the company disconnected tanks of 1,500 gal capacity used for cooling water and rinses and a 3,000 gal tank used for concentrated waste and waste acid [BSAI082571, 77]. In 1971, holding tank overflow was pH 3.4 (HCl) and 325 mg/L of copper (copper sulfate).

In 1972, a waste hauler removed contents of two buried underground tanks, one tanker truck, and one steel holding tank approximately every two weeks [BSAI082620]. On two occasions, the contents of the tanker truck contained pH 5.8 water with 160 mg/l of copper [BSAI082620} and pH 3.2 water containing 130 mg/L of copper and hundreds of µg/L of chromium, nickel, and zinc [BSAI082630-32]. In 1973, 11 drums (55 gal) and seven drums (30 gal) were disposed of. This constituted about two days of rinses if the plant could not discharge to the municipal treatment plant [Bach deposition, p. 55]. In 1979, discharge under the plant fence contained 145 mg/L of copper and 66 mg/L of chromium [BSAI082434]. In 1974, waste quantities of 4,000-6,000 gal were hauled off in trucks [BSAI00088-00092]. Concentrated and dilute aqueous streams consistent with operational processes were being disposed of during the 1970's.

Until 1979, about 55 gal/month of trichloroethylene (TCE) was used to clean machinery [BSAI082453]. Disposal to the ground, waste storage, or to recycler was a likely disposal method for this waste based on the common waste handling methods of the period.

In the 1970's, FCI disposed of large quantities of spent plating and etching baths and their rinsates off-site. Among many chemicals in these wastes were hydrochloric and sulfuric acids, copper, tin, lead, chromium, and nickel. TCE may also have been discharged in these aqueous wastes occasionally.

ETCHED CIRCUITS, INCORPORATED

In the 1970's, Etched Circuits manufactured printed circuit boards at the Cherry Hill, NJ location. Until about 1985, single and double-sided printed circuit panels were manufactured. The process during the time frame of about 1970 -1990 essentially remained the same, however [BSAI082830-082857]. The process, as described in 1990, consists of the following steps:

1. Pattern is placed on copper clad fiberglass panels with photoimagable dry film.
2. Pattern is etched into copper foil
3. Film is removed and copper pattern is oxidized.
4. Panel is dried and laminated with a layer of copper foil on each side.
5. Holes are drilled and desmeared.
6. Pattern is placed on outer foils with photoimagable dry films.
7. Panel is plated with electroless copper.
8. Film is removed and board is electroplated with copper and tin/lead composition.
9. Pattern is etched into outer copper foils.
10. Epoxy paint (solder mask) is added.
11. Tin/lead plating is fused with an infra-red oven.

Optional steps included solder stripping and plating nickel/gold to board.

The electroless copper line consisted of 22 baths of generally 130 gal tanks. The process included 10 rinses and used, among others, the following chemicals: sulfuric acid and copper complexes. The desmear line consisted of about 15 tanks of about 50 gal capacity and used, among others, sulfuric acid and potassium permanganate. The acid copper plating bath, 1425 gal, contained copper sulfate, sulfuric and hydrochloric acids, and proprietary electrochemicals. Etching used copper sulfate/ammonia and acid solutions. Waste resulted from rinsates and drag out, spent concentrated baths, spills, and periodic cleanups. Heavy metals that were used are copper, tin, lead, chromium, and nickel.

The building in which these operations occurred had a drainage trough for spill collection. As part of facility closure in 1990, chip samples were taken from the floor and walls of the building. These samples contained cyanide (maximum of 145 mg/kg), 10-117 mg/kg of chromium, 24-53,000 mg/kg of copper, 7-9,200 mg/kg of lead, 8-8,700 mg/kg of nickel, 30-

970 mg/kg of zinc [BSAI082901-082951]. These analyses are consistent with the types of operations and chemicals used by Etched Circuits.

In the 1970's, Etched Circuits disposed of spent plating and etching baths and their rinsates off-site. Among many chemicals in these wastes were hydrochloric and sulfuric acids, cyanide, copper, tin, lead, chromium, and nickel.

MERIT METAL PRODUCTS CORPORATION

Merit Metals manufactured non-ferrous metals at its facility at 242 Valley Road, Warrington Township, PA in the 1970's. Metal was cast in a foundry and machined by drilling, milling, grinding, and polishing [Wolberg deposition]. After polishing, degreasing with trichloroethylene (TCE) was performed from 1968 to 1979 [NUS Corporation, 1990, "Site Inspection Using Available Information of Merit Metals Product Corporation", R-585-6-9-68]. A portion of the products was plated with nickel and chromium in plating baths of about 2 ft .x 4 ft.

The degreasing operation would generate TCE-containing sludge and dirty TCE. The plating operation would generate spent plating solutions containing nickel, chromium, cyanide, and other chemicals. In addition, plating would generate rinsate waste containing plating chemicals. Spills and cleanout operations would also generate waste products.

In 1971, two 55-gal drums of plating rinsates were dumped illegally by Merit [Wills, A.C., February 1, 1971, Letter re Industrial Wastes, Bucks County Department of Health]. The solutions contained cyanide, chromium, nickel, and copper ions, consistent with plating operations. In 1972, wastes from the facility were stored in two 1,000-gal underground tanks and a 4,000-gal tanker truck [Hogg, E.C., February 17, 1972] Waste Inspection Report, Department of Health, PA]. Waste was hauled off-site as needed. These tanks existed from 1971-1979 [NUS, 1990].

In 1979, TCE contamination in wells near the Merit site led to a far-ranging investigation. TCE was found in the two underground tanks at 42 and 72 ppm and at 1-3 ppm in the sludge from the bottom of the tanker truck [NUS; County of Bucks, Department of Health, October 10, 1979, Letter to M.N. Silverman]. Soil below the tanks also contained TCE [NUS]. The underground TCE contamination in the wells was attributed to leakage from the tanks [NUS; International Exploration, May 1980, Hydrogeological Investigation, Merit Metals Products Co.].

In the 1970's, Merit Metals generated wastewater containing cyanide, chromium, nickel, and copper among others. The wastewater was stored in underground tanks and a tanker truck. The wastewater contained TCE from co-disposal of degreasing sludges, spent degreaser, and TCE from spills. These wastes were hauled off-site when disposal to the municipal treatment system was curtailed by plant violations.

SIGNATURE

As discovery in the litigation continues, I reserve the right to modify and/or supplement this opinion based on new information that becomes available. I am being paid \$ 175/hour and \$ 350/hour for testimony.



Jurgen H. Exner, Ph.D.

3. DOCUMENTS RELIED UPON IN THIS OPINION

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R. T. Environmental Services, Inc., June 2001, Act 2 Final Report Former Merit Metals Corporation Site, RT Project # 2462-03, Prepared for Leonard Sayles & Leonard Wolberg with appendices

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4. During testimony, I expect to use process flow diagrams to illustrate sources of wastes. Also, I expect to use drawings of chemical structures.

5. PROFESSIONAL QUALIFICATIONS

JURGEN H. EXNER

PROFESSIONAL QUALIFICATIONS

Dr. Exner has 31 years of experience in hazardous waste management and seven years in the chemical industry. He has experience in assessing environmental information and developing effective solutions based on regulatory, economic, technical, social, and legal considerations. He has expertise in site investigation, sampling and analysis, and feasibility studies, in remediation, and in the application of thermal, chemical, physical, and biological treatment methods to solve environmental problems. He has evaluated and commercialized technology by combining market and regulatory knowledge with process development skills. He has carried out laboratory treatability, pilot plant and field

demonstrations through startup of operations. Dr. Exner has built and managed technical groups and developed management strategy for entering new market areas. He provides peer review for government and technical publications.

BACKGROUND

12/1992 to present

President and Principal, JHE Technology Systems, Inc., Alamo, CA

Environmental consulting in litigation support and expert witness involved: evaluation of chemical processes for pollution by-products, examination of site contamination, fingerprinting, and validity of remediation selection, consent agreements, selection of remediation contractors, cost of remediation, proposal evaluation, technology startup operations and operational problems, cost overruns, the state of knowledge of groundwater contamination.

Management strategy for environmental protection and restoration, technology evaluation, and commercialization of new technology. Management strategy and alternative technology evaluation for soil and groundwater restoration for a \$60-300 million remediation company over the last 12 years. Summary of treatment methods for persistent organic pollutants in Asia. Expert review of remediation options at Bhopal, India. Reviewed soil and groundwater contamination at four Superfund sites and recommended treatment and containment systems for vadose and unsaturated zones, LNAPL and DNAPL. Evaluated fate of 200 pollutants in industrial surface impoundments. Developed and managed design and construction of a treatment process for uranium and radium-contaminated wastewater at a Superfund site. Prepared RCRA corrective measures study for a \$12 million site. Evaluated treatment alternatives for PCB-contaminated soil at remote locations. Regulatory assistance on two Superfund sites. Liability evaluation for international oil company.

9/1991-12/1992

Senior Vice President, Technical Development and OHM Analytical Services Corp., OHM Corporation, Walnut Creek, CA

In addition to OHM activities described below: Troubleshoot technical projects nationally, interface with clients in diverse industries as chief technical officer, develop strategy in response to government regulations, build technical capability. Managed \$6 million company analytical services group in Findlay, OH.

8/1988 to 9/1991

Senior Vice President, Technical Development, OHM Corporation, Walnut Creek, CA

Built and managed a central technical group that consulted with clients and OHM operations on technical issues related to remedial design and restoration of contaminated sites. Managed group of 15-40 at three locations. Developed new

business in thermal treatment, bioremediation, solidification, and *in situ* vapor extraction by defining technical needs, markets, permit strategies, and marketing approaches. Engaged in joint venture development, acquisitions, and developed several technology demonstrations with major clients. Directed major technical projects in biological, thermal, chemical, physical, and solidification projects on PCB, PCP, creosote, chlorinated and hydrocarbon solvents in soil and groundwater.

2/1986 to 8/1988

Vice President, Technology, International Technology Corporation, Martinez, CA

Directed technical personnel at three locations. Acquired groundwater bioremediation group for *in situ* solvent treatment and established bioremediation capability. Directed technology assessment and development, commercialized new technology. Directed dioxin assessment, site investigation, and remediation activities in U. S. and Europe.

1983 to 1986

Technical Director, IT Corporation, Martinez, CA

Established company strategy in dioxin and PCB cleanup. Directed sampling, analytical, industrial hygiene, engineering, R&D, and immediate removal activities for cleanup of dioxin, chlorinated solvents, and PCB-contaminated soil, groundwater, and buildings for industrial clients and EPA:

Work plan for remedial investigation, feasibility study, and decontamination of chlorinated solvents, pesticides, and dioxin in chemical plants in New Jersey and Hamburg, Germany. Extensive sampling and analysis in every conceivable matrix were followed by risk assessment, alternatives evaluation, regulatory and public discussion, and engineering design. Evaluation engineering in investigations and remediation of numerous dioxin-contaminated sites in Missouri.

1980 to 1983

Engineering Manager, IT Enviroscience, Knoxville, TN

Managed 12 engineers and scientists engaged in waste management activities. Program director of \$1.4 million EPA project to develop data on the fate of chemicals in biological treatment plants and for demonstration of anaerobic processes. The laboratory's chemical and engineering support activities included chemical treatment, such as oxidation and stabilization, and physical separations such as adsorption, distillation, and membrane techniques.

1975 to 1980

Senior Environmental Specialist, Hydrosience, Inc., a subsidiary of Dow Chemical, Knoxville, TN.

Conceived, developed, and managed design and startup of a chemical process for the destruction of tetrachlorodibenzo-p-dioxin. A plant was constructed and startup completed within 20 months of the initial laboratory work. The project included chemical research, sophisticated analytical methods development and application, safety and industrial hygiene, engineering scaleup, interaction with regulatory agencies, and startup troubleshooting.

Source Control and Waste Minimization - Developed a pollution abatement program for a plant site contaminated by EDC and polybrominated biphenyls. Work involved housekeeping and spill prevention, stormwater runoff, process waste characterization, and development of a carbon adsorption pretreatment process. At another specialty chemicals manufacturer, a survey of wastes and disposal options decreased waste load and costs by one third. Surveyed non-incinerable wastes of two major pharmaceutical manufacturers and devised organic chemical and heavy metal recovery processes.

1968 to 1975

Research Specialist/Project Leader, Halogens Research Lab, The Dow Chemical Company, Midland, MI

Developed dibromonitrilopropionamide biocide for cooling towers and paper mills. Registered the product with EPA and FDA, provided environmental fate and detoxification chemistry, market assessment, field trials, developmental sales, and customer contacts.

Worked out the fundamental chemistry of the process for multi-million pound per year flame retardant chemical. Followed this process through pilot plant to new plant design, worked out optimum operating conditions and initiated analytical and instrumental methods development.

Process improvements and plant operation for decabromodiphenyl oxide plant doubled plant capacity. Plant design data eliminated several waste streams and recovered valuable constituents.

Directed effort toward new uses for halogen compounds and co-invented oil well completion fluid that reached 100 million lb/year.

Carried out fundamental research in the chemistry of highly acidic media, reaction kinetics, solvent effects on organic reactions, carbonium ion chemistry, synthesis of halogenated flame retardants, effects of solvation and ion pairing on chemical equilibria, and computer analysis of chemical models.

ACADEMIC BACKGROUND

Ph. D., Organic Chemistry, University of Washington, 1968

B. S., Chemistry, University of Minnesota, 1963

NSF Graduate Fellowship 1964-1967, Phi Beta Kappa, Tau Beta Pi, Phi Lambda Upsilon, Honeywell Award

American Chemical Society, Distinguished Service Award, Division of Environmental Chemistry 1999.

PUBLICATIONS

Dr. Exner has published about 40 technical papers, holds eight patents, has edited three books on hazardous waste, and given numerous presentations. Participated in workshops by the National Academy of Science and the National Science Foundation, lectured for U.S. EPA and ACS, member of U.S. Air Force Ad Hoc Committee on Hazardous Waste (1984), member National Research Council Mixed Waste Committee 1995-1999. He was on the Editorial Board of the Journal of Hazardous Waste and Associate Editor of the Journal of the Air & Waste Management Association, and is Past-Chairman of the Division of Environmental Chemistry of the American Chemical Society, 1996-1997, and Councilor, 1998-present. He was chair of the ACS Board Committee on Environmental Improvement from 2003-2005, leading environmental issues for the world's largest scientific organization.

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P. Flathman, D. Jerger, J. Exner, Eds., "Bioremediation: Field Experience," Lewis Publishers, 1994.

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LEGAL PROJECTS/EXPERT OPINION

Pitney, Hardin, Kipp, & Szuch - Cost Allocation at Organic Chemical Plant

Reviewed documents covering the production activities at a dye and specialty organic chemical manufacturing plant that had operated from 1926-1995 under three managements. Estimated the amounts of 50-80 products that were manufactured intermittently and the quantity of waste discharged to the environment. Estimated the quantity of those chemicals discharged that were of concern during remediation. The information was combined with an assessment of RCRA and NCP compliance and the reasonableness of remediation costs.

Hunton and Williams, Richmond, VA - The case involved cost allocation for a \$135 million remediation of a wood treatment site. We examined historical documents dating to 1870, examined changes in wood treatment operations over the last century, and estimated the quantity of wood treated with creosote during operation of a wood preservation facility between 1882-

1884 based on historical records and on operability of the plant. We compared operating conditions to those used in subsequent operation from 1903-1978. We determined the probable composition of the creosote used during this time based on the state of the art of creosote production in England during the late 1800's and the probable amount of waste produced based on cost information from the period and on typical wood treatment operations. We evaluated the pathways by which the waste entered the environment (soil, groundwater, surface stream), and estimated the fate of the waste constituents in the various environmental compartments over a period of 18 years of plant inactivity. These data were related to the total waste generated throughout the plant operating time and to the proportion of remedial costs. Deposition.

Hunton & Williams, Washington, DC - North Hollywood Dump Litigation- The case involved cost allocation for landfill remediation. We reviewed the manufacturing processes for a pesticide production plant and determined the composition and quantity of probable waste streams produced in 1955-1964. We demonstrated that a prime contaminant in the landfill was produced as a 20 % by-product of the main product, heptachlor. We related sediment composition in surface water bodies near a landfill to waste transport from the landfill rather than from residential runoff. We examined background data for pollutants in the environment and in fish to identify the source pollution from the landfill. We refuted plaintiff's contentions on landfill composition based on statistical sampling methodology and hot-spot characterization. Deposition. The case was settled to our client's satisfaction.

Heller Ehrman, White, and McAuliffe, Palo Alto, CA - Fingerprinting of contaminated site to examine potential contributors to contamination. Evaluated client's and possible responsible parties process and reaction by-products, examined their presumed environmental fate (leaching, volatilization, biodegradation, chemical and uv reaction), and carried out detailed examination of mass spectral data. Examined potential remediation methods involving new technologies and prepared a critical comparison with comparative cost estimates. Participated in regulatory negotiations and reviewed proposed remediation process.

W. Koenig, Esq., Walnut Creek, CA, Collins v. Baxter- Reviewed preliminary, incomplete site investigation data from a commercial site. Estimated potential remediation costs based on an NCP-mandated cleanup. The presence of PAH components in the subsurface was traced to a closed wood treating plant. Review of historical records defined the quantity of wood produced at the site and, consequently, the amount of creosote used over a period of about 42 years. Estimated the types of wastes and quantities that may have been produced during this operation, and estimated the extent of the potential contamination. Deposition.

Hunton and Williams, Atlanta- Provided expert opinion to a PRP group on a \$ 5 million cost overrun by the remediation contractor at pesticide-contaminated sites. Examined the site investigation, feasibility study, RFP, and contract documents and reviewed the remedial operation.

Shearman and Sterling, New York, NY - A breach of contract suit on a \$60-million acquisition involved the question of potential environmental liability at a site. I evaluated from the standpoint of a prudent site operator: (1) The validity of a TCE groundwater analysis at the

method detection level, (2) The relationship of this analysis to the MCL and, therefore, the perceived risk, and (3) The probability of the site being the source of the contaminant. Prepared expert report.

Heller Ehrman/Lester Schwab, Seattle, WA and New York, NY - Hartford v. Wausau. Cost recovery litigation about the remediation of dioxin-contaminated sites in Missouri, about \$ 115 million. I examined information to address the reasonableness of the following issues and gave a deposition on:

- (1) The selection of the remediation solution by US EPA. This part involved an examination of the site investigation/feasibility study, an assessment of the health concerns by inhabitants, and description of political pressures in Missouri during the remediation selection procedure,
- (2) The procedure and rationalization that was used to estimate potential remediation costs prior to negotiation of a consent decree with the Justice Department,
- (3) The procedure used to select a contractor for remediation and the anticipated costs of part of the remediation, \$ 42 million,
- (4) The costs incurred by the government during early-phase remediation activities and in general, the difference in governmental remediation costs versus remediation by private industry,
- (5) Special factors in remediation of dioxin-contaminated sites which add to cost, public and regulatory scrutiny and review, and special precautions for protection of health and the environment.

Deposition. The client won cost recovery.

U.S. DOJ Commercial Litigation, Washington, DC - Thermacor v. US. A dispute over a large cost overrun on a PCB Superfund site. I reviewed the site data, the request for proposal, the bidding procedure, the demonstration field test of the untried technology, and the records of operation. I defined the stage of development of the technology at the time of bidding, documented assumptions made in the design of the project, and examined reasons for reduced processing rates, problems with materials handling, and equipment breakdown. I compared operating efficiencies and production problems with those experienced by three other contractors during the first application of new remediation technology. I examined a claim for patent license fees, selected an expert on metallurgy to assist on equipment issues, and recruited a geotechnical expert to address soil characteristics, another major claim issue. Gave deposition. All claims in my area of work have been denied. The case settled in February, 1997.

Crosby, Heafey, Roach, and May, Oakland, CA - The case involved an insurance claim for remediation costs of groundwater contamination by chlorinated solvents at several sites. Examined the popular and technical literature between 1959-1977 to assess the environmental awareness of the public and the technical knowledge of groundwater issues during that time period and gave deposition.

Crosby, Heafey, Roach, and May, Oakland, CA - I provided technical advice on the fate of polymethylmethacrylate in wood, identified a polymer expert, and was deposed. The case was settled in 1998.

Pettit and Martin, San Francisco, CA - MRCP Realty Company v. Esselte Pentaflex. The case involved soil and groundwater contamination at a commercial site. I evaluated geological and hydrogeological data, analyses on methyl isobutyl ketone, and examined whether site contamination occurred during a particular time period.

PARTIAL LIST OF PUBLICATIONS – 1995-PRESENT

Birke, V., Burmeier, H., Poggendorf, C., Schenker, F., Exner, J.H., "Site Assessment and Accelerated Feasibility Study for Clean-Up of the Former Union Carbide Pesticide Plant at Bhopal, India," Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds," May 22-25, 2006, Monterey, CA

Exner, J.H., "Science and Policy: Who Speaks for Science," C&EN, December 12, 2005, p. 30

Exner, J. H., "Toward a Global Environmental Ethic," C&EN, April 18, 2005, p. 49

Exner, J. H., "Global Climate Change and Citizen Chemists," C&EN, March 29, 2004, p. 45

Mahaffey, W.R., Mickel, C.E., Exner, J.H., Bowman, R., "Advanced chemical oxidation & fixed film bioreactor treatment train for remediation of MTBE impacted groundwater," Battelle 6th International *In Situ* and On-Site Bioremediation Conference, San Diego, CA, June 4-7, 2001

Exner, J. H., "Scientific Uncertainty and Risk Management," American Chemical Society 220th National Meeting, Washington, DC, August 2000, Division of Environmental Chemistry Symposium.

Dejonghe, P., Clarke, A., Exner, J., Hansen, K., Lighty, J., Samelsen, R., Steindler, M., Thomson, B., "Waste Forms for DOE Mixed Waste," National Academy Press, Washington, DC, 1998.

Exner, J., "Alternatives to Incineration in Remediation of Soil and Sediments Assessed," Remediation, Summer 1995, pp. 1-18.